ABRATES

Journal of Seed Science
ISSN 2317-1545
www.abrates.org.br/revista

ARTICLE

Quality of corn seed industrial seed treatment (IST) and on-farm treatment (OFT) in Brazilian agribusiness

Journal of Seed Science, v.45, e202345017, 2023

http://dx.doi.org/10.1590/2317-1545v45268856

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ABSTRACT: Seed treatment is important for protecting seed and seedling from pests and/or pathogens. Seed treatment can be performed generally in two ways: industrial seed treatment (IST), performed by seed companies, or on-farm treatment (OFT). These treatment technologies will affect the final quality of the process. Therefore, the objective of this study was to characterize the seed quality profile of ISTs and OFTs in Brazilian agribusiness in terms of functional quality and dose application effectiveness (DAE). Seed samples treated by both processes were collected in 6 producing states of Brazil, Mato Grosso, Goiás, Paraná, Minas Gerais, São Paulo, and Santa Catarina. To evaluate the functional quality of the treatments, the coating percentage was determined by high-resolution image analysis with GroundEye® equipment, and the insecticide active ingredient DAE amount was determined with high-performance liquid chromatography (HPLC). Image analysis proved to be a promising technique to evaluate seed coating, in addition, samples treated with "on farm" technology had greater variation and heterogeneity in coating and active ingredient dose, while samples treated industrially showed greater homogeneity, uniformity, effectiveness of applied products. There was a strong positive correlation between coating with phytosanitary products and DAE in treated corn seeds, important parameters in the evaluation of the quality of the treatment.

Index terms: application effectiveness, chemical treatment of seeds, functional quality, seed coating.

RESUMO: O tratamento de semente é importante para a proteção de sementes e plântulas contra pragas e ou patógenos. Podendo ser realizado basicamente via tratamento de sementes industrial (TSI) ou na própria fazenda "*on farm*" (TOF). Essas tecnologias de tratamento vão afetar a qualidade final do processo. Assim, o objetivo no trabalho foi realizar a caracterização do perfil da qualidade do TSI e TOF no agronegócio brasileiro, quanto à qualidade funcional e eficácia de aplicação de dose (EAD). Sementes tratadas em ambos os processos foram coletadas em 6 estados produtores do Brasil e avaliadas quanto à porcentagem de recobrimento por meio da análise de imagens com o equipamento GroundEye® e EAD do ingrediente ativo inseticida por meio de Cromatografia Líquida de Alta Eficiência (CLAE). A análise de imagem mostrou-se uma técnica promissora para avaliar o recobrimento de sementes, além disso, as amostras tratadas com a tecnologia "on farm" apresentaram maior variação e heterogeneidade do revestimento e da dose do ingrediente ativo, enquanto as amostras tratadas industrialmente houve maior homogeneidade, uniformidade, assertividade dos produtos aplicados. Existe forte correlação positiva entre recobrimento por produto fitossanitário e EAD em sementes tratadas de milho, parâmetros importantes na avaliação da qualidade do tratamento.

Termos para indexação: eficácia de aplicação, tratamento químico de sementes, qualidade funcional, recobrimento de sementes.

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Received: 10/21/2022.
Accepted: 02/13/2023.

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INTRODUCTION

Currently, the application of phytosanitary products in the form of seed treatment has gained prominence, and when applied well, it protects seeds and seedlings, favors their initial development mainly under water restriction in the soil, and may lead to a decrease in the use of active ingredients per area and lower environmental risks (Aguiar et al., 2018; Lacerda et al., 2021; Carvalho et al., 2022b; Moraes et al., 2022).

Seed treatment can be generally performed with two application technologies, on-farm treatment (OFT) commonly called *"on-farm"* or industrial seed treatment (IST). In the OFT, the treatment is performed on a farmer's property, under his or her supervision and/or with his or her technical assistance, and in general with lower capacity equipment. This type of treatment involves substantial variability in equipment and technological levels of application (Ludwig et al., 2011).

In contrast, the IST process is performed by the seed producer or a specialized company as part of the seed processing (Brzezinski et al., 2015; Silva et al., 2020). The technique consists of using professionals, products, polymers for adhesion, machines, and specific equipment for seed treatment (Abrasem, 2015; Ludwig, 2017). The adoption of this type of treatment has increased in Brazilian agribusiness, and several companies offer this treatment (Ferreira et al., 2016; Carvalho et al., 2020).

Different products and their compositions can be used in seed treatment, and these factors can positively or negatively affect the physiological quality of seeds (Santos et al., 2018; Carvalho et al., 2022a). Highlighting, some insecticide molecules may cause phytotoxicity, which impairs the germination and vigor of corn seeds (Mariucci et al., 2018; Oliveira et al., 2020), therefore, they demand more attention and a careful use, as it is believed that such negative effect can be enhanced when the treatment is not conducted correctly.

However, in addition to the products and spray volumes, the product application technology and the seeds can also influence the final result of the process. Similar to the results reported by Peske (2019) for soybean seeds, the samples with the IST had higher dose application effectiveness than the OFT samples. However, in the case of maize seeds, which are more complex in terms of product coating and adherence, there is still little scientific information about the quality of seed coating and dose application effectiveness (DAE) as a function of treatment technology.

Thus, the objective of this study was to characterize the quality profile of ISTs and OFTs in Brazilian agribusiness in terms functional quality and dose application effectiveness through the analysis of high-resolution images and high-performance liquid chromatography (HPLC).

MATERIAL AND METHODS

The study was developed in partnership with the Central Seed Laboratory of the Department of Agriculture (DAG), School of Agricultural Sciences of Lavras (ESAL) of *Universidade Federal de Lavras* (UFLA), Lavras, Minas Gerais, Brazil, and the Seedcare Institute, Syngenta, Holambra, São Paulo, Brazil.

Seed samples of treated maize hybrids were randomly collected in 6 producing states of Brazil, Mato Grosso, Goiás, Paraná, Minas Gerais, São Paulo and Santa Catarina. For the collection of all samples, in addition to fungicidal treatment Maxim Advanced® (metalaxilm (2% - 20 g.L^{-1}), thiabendazole (15% - 150 g.L^{-1}), fludioxonil (2,5% - 25 g.L^{-1}), 30 mL.60,000 seeds^{-1}), a commercial insecticide treatment with Cruiser 600 FS® at the recommended dose of 70 mL.60,000 seeds^{-1}, with the active ingredient thiamethoxam (60% - 600 g.L^{-1}), or with Fortenza 600 FS® as the recommended dose of 70 mL.60,000 seeds, with the active ingredient Ciantraniliprole (60% - 600 g.L^{-1}), was applied. Among the samples that met the assumptions, 17 samples were from different IST units, and 17 were collected from farmers in the same regions subjected to the on-farm treatment. The origins and active insecticidal ingredients are listed in Table 1.

The collected seed samples were designated according to the treatment technology, such as IST and OFT. After collection, identification, and homogenization, the seeds were analyses:

Table 1. Origin of the samples used to compose the survey of the quality of the industrial seed treatment and the on-farm treatment of the corn seed in Brazilian agribusiness.

Name	Region	Active Ingredient	Name	Region	Active Ingredient
OFT-1	Mariluz - PR	Thiamethoxam	IST-1	Ipuã-SP	Thiamethoxam
OFT-2	Moreira Sales - PR	Thiamethoxam	IST-2	Ipuã-SP	Thiamethoxam
OFT-3	Uberlândia - MG	Thiamethoxam	IST-3	Formosa-GO	Thiamethoxam
OFT-4	Rio Verde - GO	Thiamethoxam	IST-4	Goianésia-GO	Thiamethoxam
OFT-5	Uberlândia - MG	Thiamethoxam	IST-5	Goianésia-GO	Thiamethoxam
OFT-6	Uberlândia - MG	Thiamethoxam	IST-6	Paracatu-MG	Thiamethoxam
OFT-7	Rondonópolis - MT	Thiamethoxam	IST-7	Matão-SP	Thiamethoxam
OFT-8	Guiratinga - MT	Thiamethoxam	IST-8	Goianésia-GO	Thiamethoxam
OFT-9	Itumbiara - GO	Thiamethoxam	IST-9	Gardening-SP	Thiamethoxam
OFT-10	Rio Verde - GO	Thiamethoxam	IST-10	Formosa-GO	Thiamethoxam
OFT-11	Rio Verde - GO	Thiamethoxam	IST-11	Paracatu-MG	Thiamethoxam
OFT-12	Chapecó - SC	Thiamethoxam	IST-12	Paracatu-MG	Thiamethoxam
OFT-13	Rio Verde - GO	Thiamethoxam	IST-13	Matão-SP	Thiamethoxam
OFT-14	Rio Verde - GO	Cyantraniliprole	IST-14	Paracatu-MG	Cyantraniliprole
OFT-15	Lucas do Rio Verde - MT	Thiamethoxam	IST-15	Matão-SP	Thiamethoxam
OFT-16	Patos de Minas - MG	Thiamethoxam	IST-16	Paracatu-MG	Thiamethoxam
OFT-17	Goiatuba- GO	Cyantraniliprole	IST-17	Paracatu-MG	Cyantraniliprole

OFT: “on-farm” treatment; IST: industrial seed treatment.

Analysis of the percentage of seed coating: corn seed with coating images were captured and processed, in eight replicates of 50 seeds for each IST and OFT. To calibrate the system, it was necessary to capture and process images from a batch without chemical treatment. High-resolution images were captured and processed using the GroundEye® image analysis system, version S800. After the acquisition of the images, the analysis configuration was performed to calibrate the background color of the treated and untreated seeds to quantify the seed coating was performed generated by the GroundEye® software, and thus, it was possible to select the color dominance characteristic for evaluating the seed coating. The results of seed color dominance were obtained as a percentage of color to quantify the coating of the treated seeds.

Active ingredient dose application effectiveness: The analytical chemical technique used was HPLC, which allowed the separation, identification, and quantification of the active ingredients thiamethoxam and cyantraniliprole, which were the insecticides used in the seed treatments. The samples were analyzed in the Agilent 1260 Infinity II equipment, which has a solvent booth system, quaternary pump, injector, chromatographic columns, variable wavelength detector (VWD) detector, and computer with analytical software (Agilent, 2022).

For analysis, 200 maize seeds were used in triplicate for each of the treatments, and samples. To extract the samples, specific solvents were added. An aliquot of the filtrate was removed and transferred to a volumetric flask. The content was then transferred to performing injections in the chromatograph and reading the data using OpenLab software.

To quantify the insecticide thiamethoxam or cyantraniliprole by HPLC, the specific parameters used by the Laboratory of the Seedcare Institute Latin America - Syngenta were used: chromatographic column, mobile phase, mobile phase flow, wavelength, injection volume, and column temperature, with a time retention time of approximately 6 minutes. The software automatically calculates the result in $g.kg^{-1}$. The results of the analyzed samples were transformed into the percentage of correct dose.

Statistical analysis: A completely randomized design (CRD), with eight replicates for the image analysis and three replicates for the analysis of the active ingredient dose by HPLC, was used. The data were analyzed using descriptive statistics, calculating the mean, minimum, maximum, standard deviation, frequency of distribution, and normal distribution curve. The data were also subjected to analysis of variance at 5% probability by the F test, and when significant, the Scott–Knott test was applied at 5%. The data were submitted to Pearson's linear correlation matrix using the correlogram method ($p<0.05$) for the percentage of coating and active ingredient dose application effectiveness amount by treatment type, IST and OFT.

Seven samples from the group of OFT seeds had graphite and could not be used in the image analysis of the coating. The graphite prevented and altered the identification of the percentage of treatment coating for 10 samples from the IST group. Thus, 10 OFT samples and 10 IST samples were used to perform the cluster analysis of means of equal coating coverage and for the correlation of the percentage of coating with the active ingredient dose application effectiveness amount. Thus, 10 IST samples were randomly selected: IST-6, IST-7, IST-9, IST-10, IST-12, IST-13, IST-14, IST-15, IST-16, and IST-17 were used for the coating analysis, and 10 OFT-1, OFT-2, OFT-4, OFT-5, OFT-6, OFT-8, OFT-9, OFT-11, OFT-14 and OFT-16 were used without the use of graphite.

The computational software Excel and R version 3.5.1 with the "ExpDes.pt" (Ferreira et al., 2014) and "Hmisc" (Harrell-Junior and DuPont, 2014) packages were used to perform all analyses and graphs (R Development Core Team, 2016).

RESULTS AND DISCUSSION

To properly acquire and process the high-resolution images, the CIELab color parameter was defined for the OFT seed samples with a luminosity index from 0 to 100, dimension "a" -18.0 to 42.0, and "B" -54.5 to -14.5." For the IST seed samples, the color parameter YCbCr was used luma index 0.09 to 0.66, a blue index 0.00 to 0.50, and a red index -0.30 to 0.11. For the untreated seeds, the CIELab color parameter, luminosity index from 0 to 100, dimension "a" -19.1 to 40.9, and dimension "b" from -70.5 to 1.4". The minimum size of the object used was 0.08 cm^2 for all configurations. After the analysis of the high-resolution images, the sum of the red and pink colors was defined as dominant, while the orange and yellow colors were defined as areas not covered by the phytosanitary product, as a function of the predominance of the product colors observed in the treated and untreated seeds (Figures 1A, B and C).

In the IST samples, a coating of 98% was found, whereas for the OFT seeds, the average was 88% coating. For both treatment types, in the covered areas, there was a predominance of red compared to pink. The OFT seeds had a mean chemical coating of 12% compared to only 2% for IST seeds, which may affect the efficiency and protection provided by the phytosanitary products due to their incorrect distribution on the seed surface (Figures 1A, B and C).

For the individualized analyses, in comparison to the IST samples, the OFT samples had greater variation and heterogeneity with a maximum observed coating value of 98% and a minimum coating value of 64%, a difference of 34% (Figure 2A). For the IST samples, there was greater coating homogeneity, with a maximum coating variation of 4%, with a 99% coating maximum and 95% coating minimum (Figure 2B). Adequate product coating and distribution on the seed surface are important to ensuring the benefits of seed treatment (Afzal et al., 2020). A good quality treatment and coating of maize seeds provide better adhesion of the applied products in addition to reducing the number of flaws and need for double sowing (Avelar et al., 2012).

Considering a satisfactory coating is above 90%, it was found in the present study that only 68.8% of the OFT samples had more than 93% coating, whereas 100% of the IST samples had a coating above 93% (Figure 3). An excellent coating is considered above 95%, and only 46.3% of the OFT samples reached this quality standard; however, 97.5% of the IST samples met this quality standard (Figure 3). In addition, for the coating percentage, the IST samples had a more concentrated normal distribution curve, close to the mean of 98% and lower standard deviation, i.e., a higher probability of obtaining samples close to this coating; however, for the OFT samples, a flatter distribution

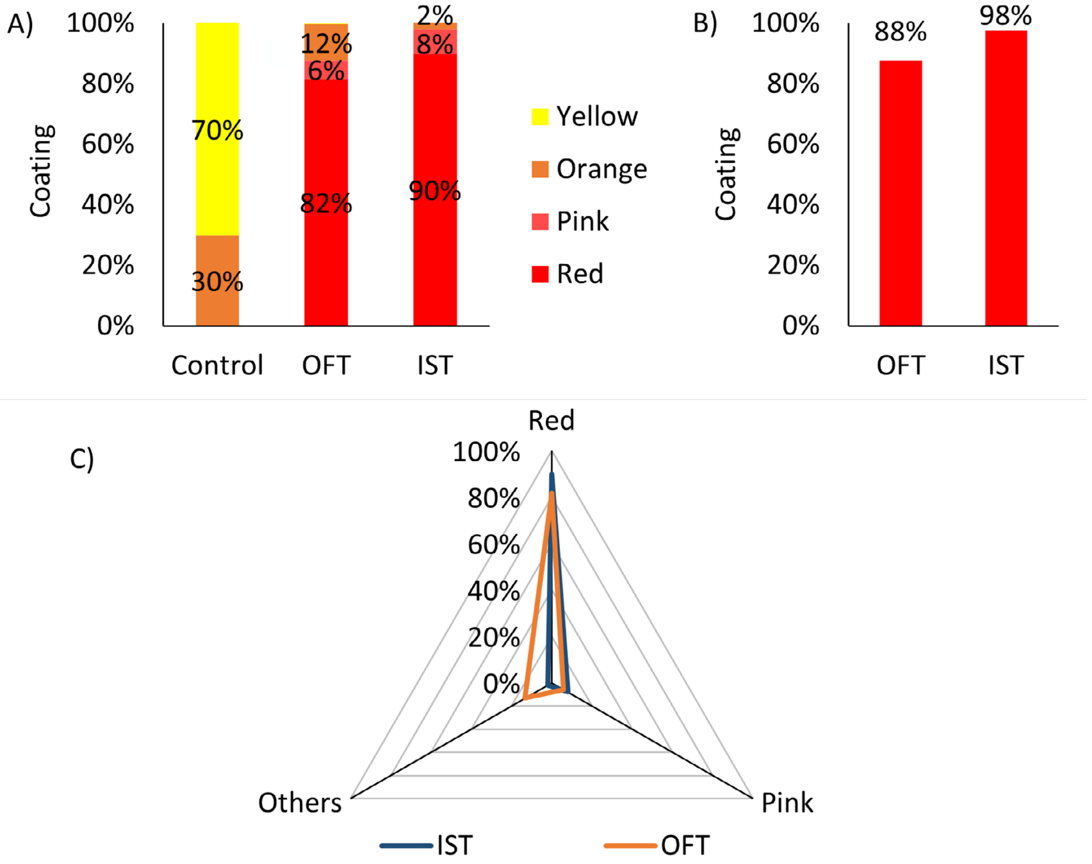

Figure 1. Percentage mean of the coating of seeds subjected to the industrial seed treatment (IST) and on-farm treatment (OFT) of corn seeds in different locations in Brazil. A) Average percentage of color dominance for the untreated samples (control) and for the samples subjected to the IST and OFT. B) Average percentage of total coating of the IST and OFT samples. C) Means presented in the radar graph as a function of the color dominance of the coatings.

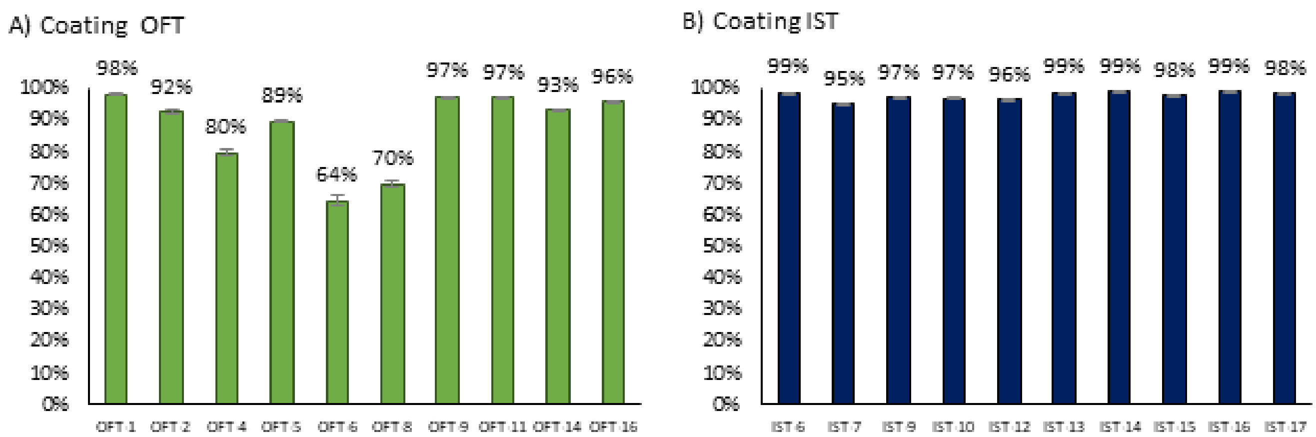

Figure 2. Percentage of phytosanitary product coating on the corn seed samples according to the application treatment, on-farm treatment (OFT) (A) and industrial seed treatment (IST) (B).

curve was observed compared to the mean of 88%, with greater standard deviation, which indicates greater variability and heterogeneity between the samples (Figure 4). A good product coating and a good distribution on the seeds are important parameters for evaluating the quality of seed treatment and protection (Pes et al., 2020; Javed et al., 2022).

In the comparison of the means, in the group containing the seed samples with the highest mean coating values, whose values were between 97.7% and 99.1%, six of the seven samples were in the IST, i.e., 85.7% of the samples, and only one sample of seeds (14.3%) was in the OFT (OFT 1). In the second classified group, with values between 97.3% and 96.4%, the predominance of IST samples was maintained. The four worst coating averages, which differed from each other, with values between 89.4% and 64.3%, were for OFT samples (Table 2).

To illustrate the visual differences in the coatings in Figure 5, the 4 samples with the best coatings and the 4 with the worst coatings are presented. The differences between the samples are easily perceived by the naked eye, but more subtle differences are difficult to separate, which leads to great subjectivity and chances of errors in the visual classifications of the coating quality, a common practice for many companies and producers. With high-resolution image analysis, it was possible to quantify the percentage of coating, ensuring an accurate evaluation and avoiding subjectivity in quality control. In addition to the higher coating mean in the IST, it was also possible to observe a more uniform distribution of the coating in relation to that in OFT, where flaws in the coating process were observed.

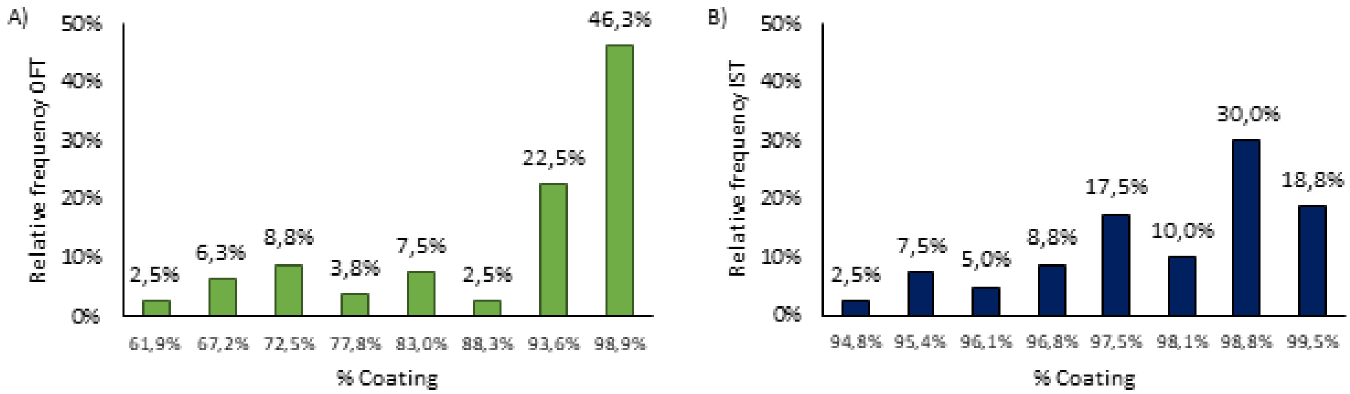

Figure 3. Relative frequency of the percentages of phytosanitary product coating on the corn seed samples as a function of the application treatment, on-farm treatment (OFT) (A) and industrial seed treatment (IST) (B).

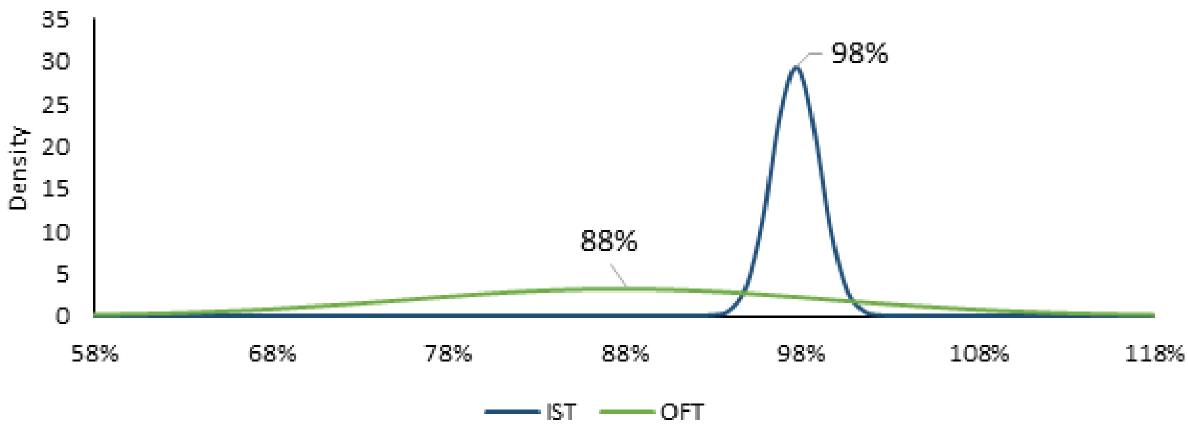

Figure 4. Curve of the normal distribution of the percentages of phytosanitary product coating on the corn seed samples according to the application treatment, on-farm treatment (OFT) and industrial seed treatment (IST).

Table 2. Coating of maize seed samples according to the application treatment, on-farm treatment (OFT) and industrial seed treatment (IST).

Treatments	% Coverage
IST-14	99.1% a
IST-16	98.9% a
IST-12	98.7% a
IST-6	98.6% a
IST-17	98.5% a
OFT-1	98.2% a
IST-15	97.7% a
OFT-9	97.3% b
OFT-11	97.1% b
IST-9	96.9% b
IST-10	96.9% b
IST-11	96.4% b
OFT-16	95.6% c
IST-8	95.0% c
OFT-14	92.9% d
OFT-2	92.5% d
OFT-5	89.4% e
OFT-4	79.6% f
OFT-8	69.6% g
OFT-6	64.3% h
CV (%)	1.51

Means compared by the Scott–Knott clustering test ($p<0.05$).

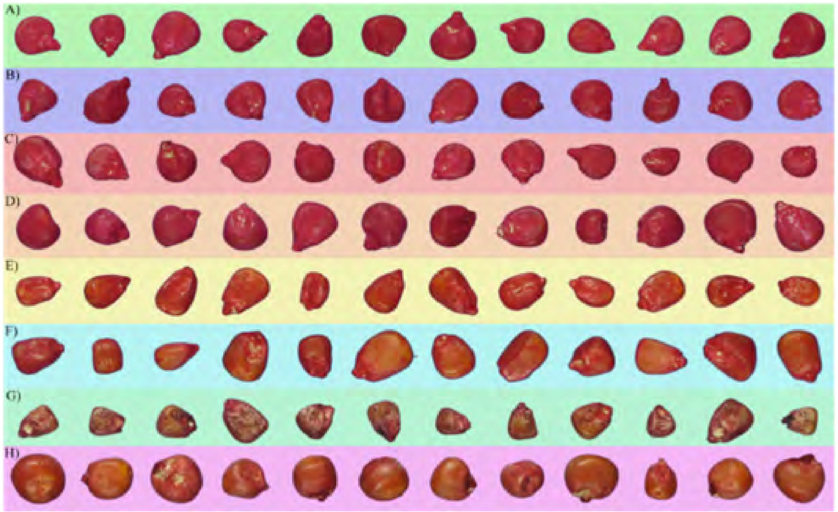

Figure 5. Sample of maize seeds subjected to treatment with phytosanitary products according to the application treatment, on-farm treatment (OFT) and industrial seed treatment (IST). A) Sample IST-14; B) IST-16; C) IST-12; D) IST-6; E) OFT-5; F) OFT-4; G) OFT-8; H) OFT-6.

Image analysis has been adopted as a promising technique for ensuring internal quality control for companies and institutions with different objectives. How to using the CIELab system, which has been shown to be promising in the classification of color patterns, image analysis has been used to classify and register triticale seed cultivars (Buratto et al., 2021). In corn seed lots, image analysis techniques such as radiography and X-ray images have been successfully used to detect mechanical damage and damage caused by insects in corn seeds (Carvalho et al., 2019; Ribeiro et al., 2019). Additionally, physiological potential has been verified with image analysis of the coleoptile and radicle of maize seedlings (Pinto et al., 2015).

Seedling-assisted images obtained with a digital camera have been analyzed with the computational software ImageJ®, which was successful in evaluating seedling morphological parameters for quality control in tomato seed lots (Oliveira et al., 2021). In cowpea and soybean seed lots, the Automated Seed Vigor Analysis System was also an efficient alternative to detect differences in vigor and determine the physiological potential between the lots (Rodrigues et al., 2020; Rego et al. al., 2021). Acha and Vieira (2020), using GroundEye® equipment, concluded that digital image analysis is effective in accurately determining the physical characteristics of perennial soybean seeds with different coatings. Decarli et al. (2019), evaluating the two IST and OFT methods in soybean seeds according to the Burris visual scale (s.d.) method, found that industrial seed treatment provided better seed coating for different cultivars. However, visual analyses are more subject to subjectivity, so studies and adjustments are still needed for the application of high-resolution image analysis in the quality control of treated seeds.

Another important parameter for evaluating the functional quality of treated seeds is the quantity distribution of active ingredient (ai), determining how much was actually applied in relation to the recommended dose, or the active ingredient dose application effectiveness amount. For this analysis, all 34 samples were used, with 17 IST samples and 17 OFT samples. The mean insecticidal active ingredient dose application effectiveness amount in the OFT samples was 95%, while it was 100% for the IST samples (Figure 6). However, with the individualized analysis of the samples, the same trends observed for coating were observed for DAE, greater heterogeneity for the OFT samples and greater homogeneity for the IST samples. For the OFT samples, the DAE amounts varied between 7% and 220% of the recommended dose, an oscillation of 213 percentage points (Figure 7A). This level of DAE may cause low efficacy of the insecticide against pests due to the low dose or an occurrence of phytotoxicity due to the excessive amount of active ingredient when an overdose occurs. A high dose application effectiveness in a seed treatment is extremely important, especially in the case of some phytosanitary molecules, such as insecticides, that tend to have varied phytotoxicity depending on the active ingredient, especially in relation to fungicides (Corlett et al., 2014; Rocha et al., 2020; Carvalho et al., 2022a; Moraes et al. 2022).

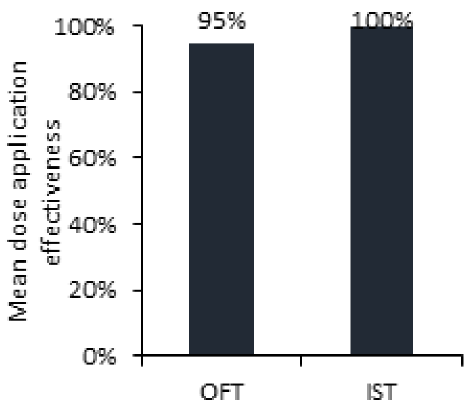

Figure 6. Mean percentage of active ingredient dose application effectiveness in the corn seed samples as a function of application treatment, on-farm treatment (OFT) and industrial seed treatment (IST) in different locations in Brazil.

For the IST samples, the variation was lower, with 92% of the minimum value to 105% of the maximum value, a variation of 13 percentage points, reiterating the greater uniformity observed in the coating (Figure 7B). All values were above 90%, thus demonstrating high precision in the application of insecticide to seeds when performed by specialized companies.

This fact becomes more explicit when analyzing the relative frequency of dose application effectiveness. For the OFT samples, only 41.2% showed results close to the desired outcome, with a variation of 10% up or down, i.e., between 90 and 110% (Figure 8A). In contrast, 100% of the IST samples were between the desired values, between 90 and 110% (Figure 8B). As for the coating, the IST samples were more concentrated near the average of 100%, whereas the OFT samples showed greater heterogeneity and had a lower density close to the average of 95% (Figure 9).

In the grouping test of means presented in Table 3 on dose application effectiveness, considering the recommended values between 90 and 110% of the ideal dose, among the 18 samples in this test, 17 were treated with the IST technology, i.e., all IST samples and only one OFT sample, composing the groups "g", "h", and "i". The other extreme and statistically distinct values were composed of OFT samples, with effectiveness amounts of 172 and 202%, which tended to increase phytotoxicity problems, such as reduced germination and seedling development, especially in terms of root length (Carvalho et al., 2020), because although the phytotoxic effect of various chemicals can be tolerated to a certain amount, most seedlings show growth and development disorders, especially at higher chemical concentrations (Kilic et al., 2015).

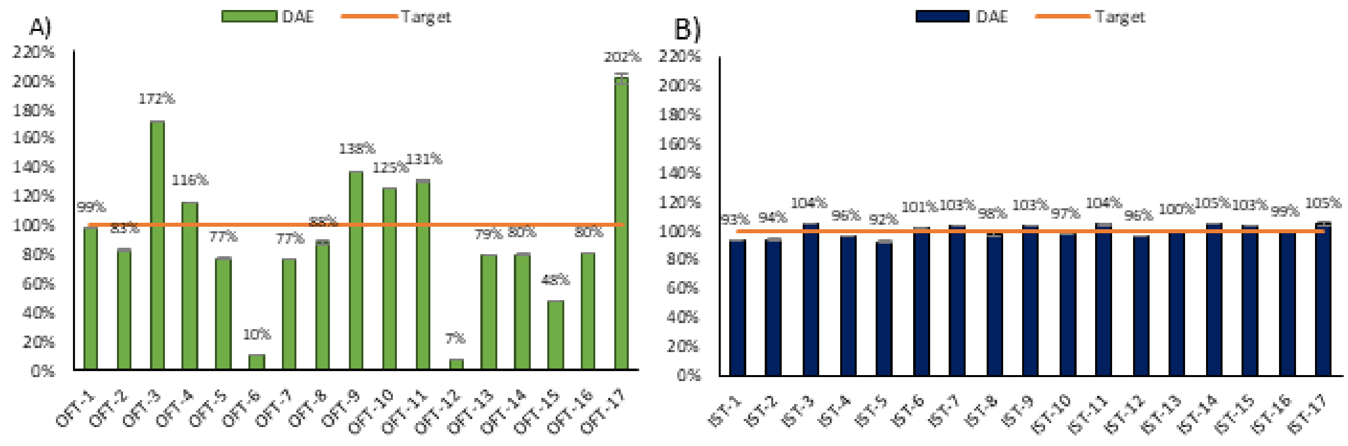

Figure 7. Percentage of active ingredient dose application effectiveness (DAE) on the corn seed samples according to the application treatment, on-farm treatment (OFT) (A) and industrial seed treatment (IST) (B).

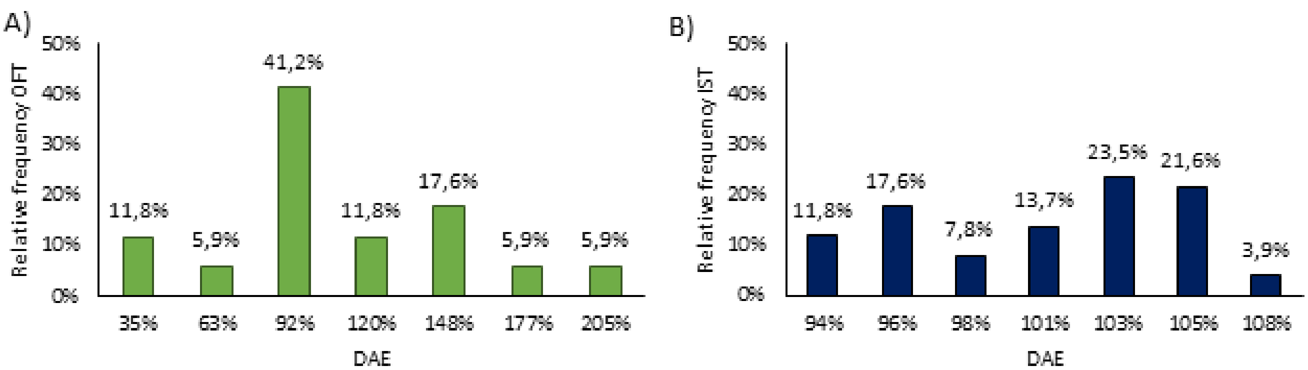

Figure 8. Relative frequency of the active ingredient dose application effectiveness (DAE) on the seeds subjected to on-farm treatment (OFT) (A) and industrial seed treatment (IST) (B).

Similarly, 48, 10 and 7% of DAE amount compromised the efficiency of the products in protecting seeds and seedlings. This result supports that the IST methods is superior in terms of its ability to provide a strong commercial production application and consequently the insecticidal active ingredient, highlighting the importance correctly and professionally applying these methods, whether in the farm or in the seed treatment industry, to ensure successful protection of seeds and seedlings to ensure the seed treatment benefits the crop (Freiberg et al., 2017).

The correlation of 0.63 (63%) observed in the correlogram matrix (Figure 10) between the percentage of coating and active ingredient dose application effectiveness can be considered strong (Evans, 1996) and positive; i.e., the greater the coating is, the greater the active DAE. This relationship between the two characteristics is interesting because in comparison to HPLC, image analysis is a fast and nondestructive test, in addition to inexpensive, favoring companies and producers during the seed treatment stage in terms of ensuring a quick decision-making process and a quality treatment process.

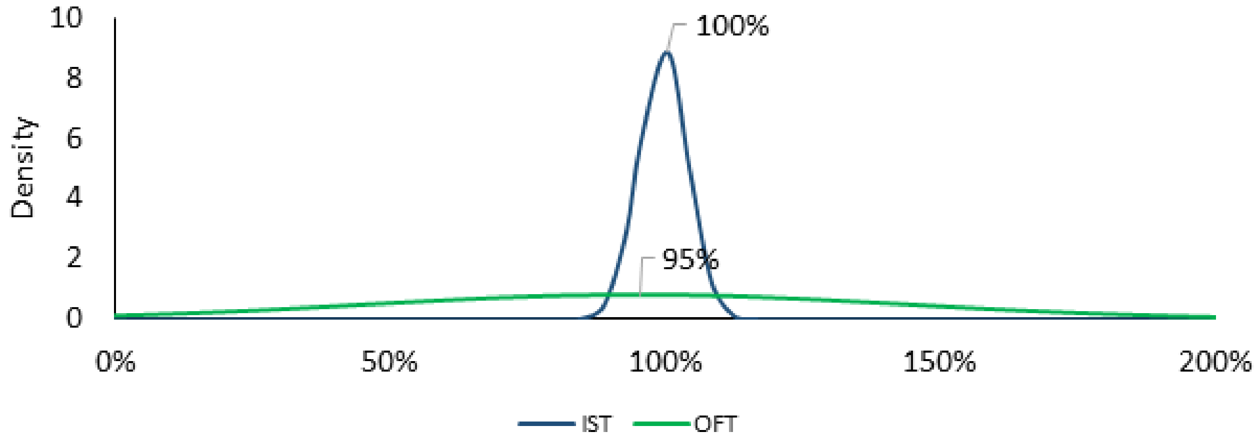

Figure 9. Curve of the normal distribution of the active ingredient dose application effectiveness on the corn seed samples according to the application treatment, on-farm treatment (OFT) and industrial seed treatment (IST).

Table 3. Active ingredient dose application effectiveness on the corn seed samples according to the application treatment, on-farm treatment (OFT) and industrial seed treatment (IST) in Brazilian agribusiness.

Treatments	Effectiveness related to the reference dose of the active ingredient
OFT-17	201.7% a
OFT-3	172.4% b
OFT-9	137.6% c
OFT-11	131.4% d
OFT-10	125.2% e
OFT-4	116.2% f
IST-14	105.0% g
IST-17	105.0% g
IST-11	104.3% g
IST-3	104.3% g
IST-9	103.0% g
IST-15	102.9% g

Continue...

Table 3. Continuation.

Treatments	Effectiveness related to the reference dose of the active ingredient
IST-7	102.9% g
IST-6	101.4% g
IST-13	100.0% h
OFT-1	98.6% h
IST-16	98.6% h
IST-8	97.6% h
IST-10	97.1% h
IST-12	95.7% i
IST-4	95.7% i
IST-2	93.8% i
IST-1	93.3% i
IST-5	92.4% i
OFT-8	88.1% j
OFT-2	82.9% k
OFT-16	80.5% l
OFT-14	80.0% l
OFT-13	79.0% l
OFT-5	77.1% m
OFT-7	76.7% m
OFT-15	48.1% n
OFT-6	10.3% o
OFT-12	7.5% o
CV (%)	1.96

Means compared by the Scott–Knott clustering test (p<0.05).

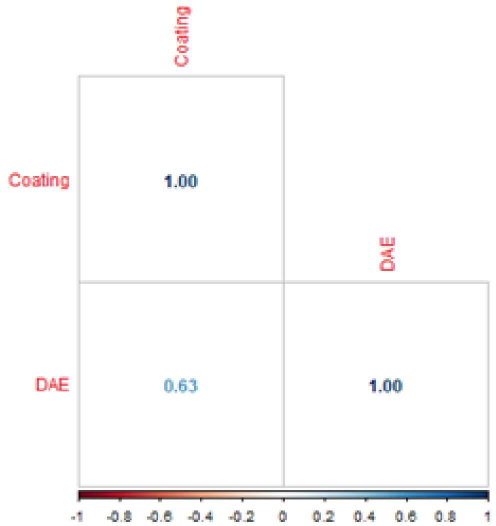

Figure 10. Correlation matrix (correlogram) between the percentage of coating and active ingredient dose application effectiveness (DAE). Values of r in blue indicate a positive correlation, and r values in red indicate a negative correlation. Significant p-test (p <0.05).

CONCLUSIONS

High-resolution image analysis is efficient for measuring the coating of treated corn seeds and contributes to the evaluation of this parameter in quality control.

In comparison to the OFT seeds, the IST seeds had greater pesticide coatings and higher active dose application effectiveness amounts.

There was a strong positive correlation between the coating of phytosanitary products and dose application effectiveness amounts in the treated corn seeds.

ACKNOWLEDGMENTS

The authors thank the *Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq* and *Fundação de Amparo à Pesquisa do Estado de Minas Gerais - FAPEMIG* for their support and the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES) for their financial support, scholarships granted and the Productivity in Research (CNPq) scholarship.

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